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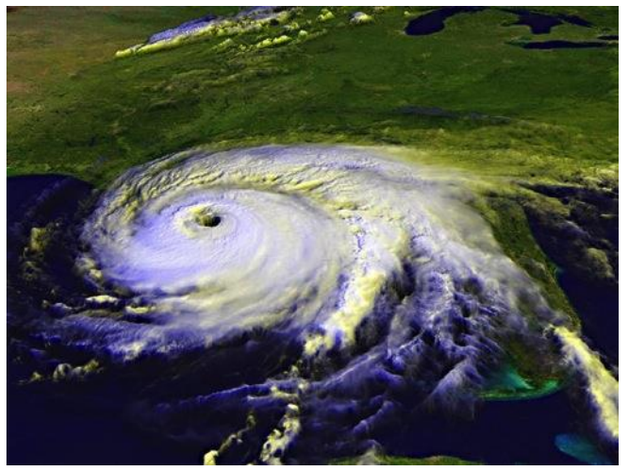

Ionic Liquid Flow Battery

Wednesday, September 17, 2014

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U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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Acknowledgements

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Project Overview

Problem: Ionic liquid flow batteries suffer from high viscosities, but hold the promise of higher energy densities due to higher metal concentrations and wider voltage windows.

Innovative 3-fold Approach: New multi-valent anode/cathode materials by judicious ligand/anion selection for lower viscosity, tunable membranes for non-aqueous compatibility, AND rapid laboratory-scale prototyping to quickly evaluate materials and cell designs.

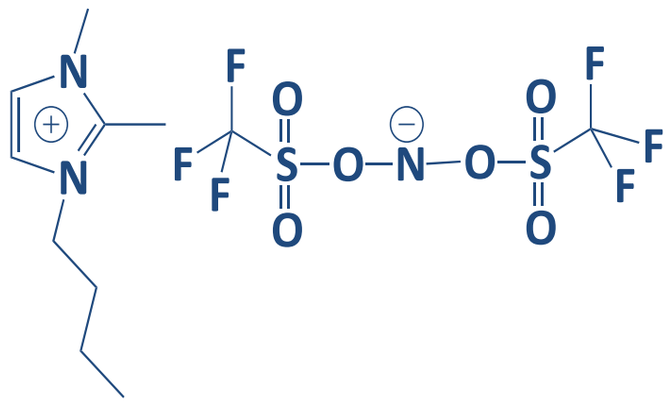
Target Metrics

- 59 mV/n separation (n > 1)
- Viscosity < 500 cP
- Conductivity > 0.5 mS/cm
- OCP > 1.5 V

Energy Density$_{RFB}$ ≈ ½nFV$_{cell}$c$_{active}$

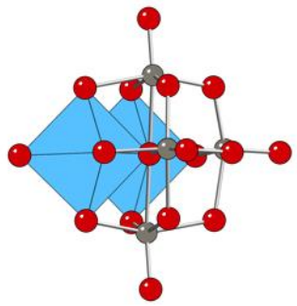
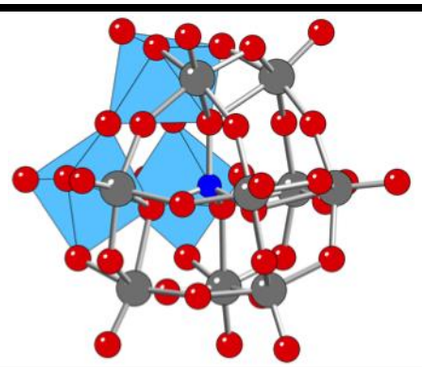
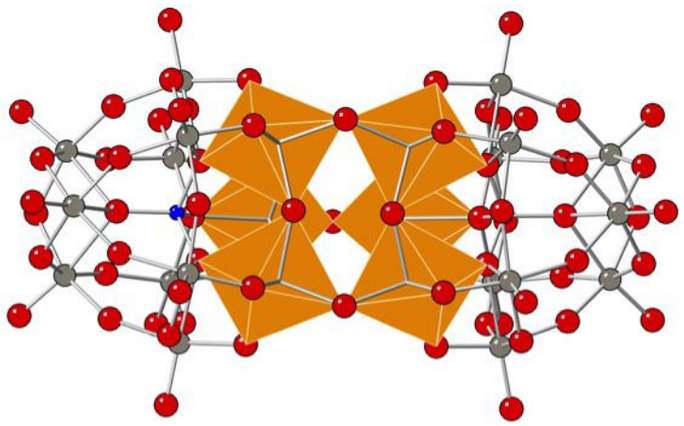
$ED_{AQ} = ½1F1.5_{cell}2_{active}$ = **1.5F**

$ED_{IL} = ½2F2_{cell}3_{active}$ = **6.0F**



Four-Fold Improvement

Tunable Anions

Structure	Oxidized (charge/Å^3)	Reduced (charge/Å^3)	CE	EY
	0.16	0.32	45%	16%
	0.13	0.24	95%	90%
	0.11	0.16	83%	55%

The size and charge density of the ions are crucial factors to consider when optimizing battery performance.

H.D. Pratt III *et al. Electrochimica Acta* **2014**, *138*, 210-214.

Ionic Liquid RFB Prototype

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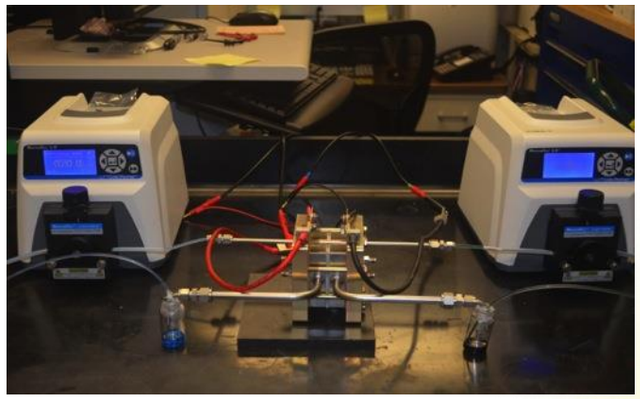
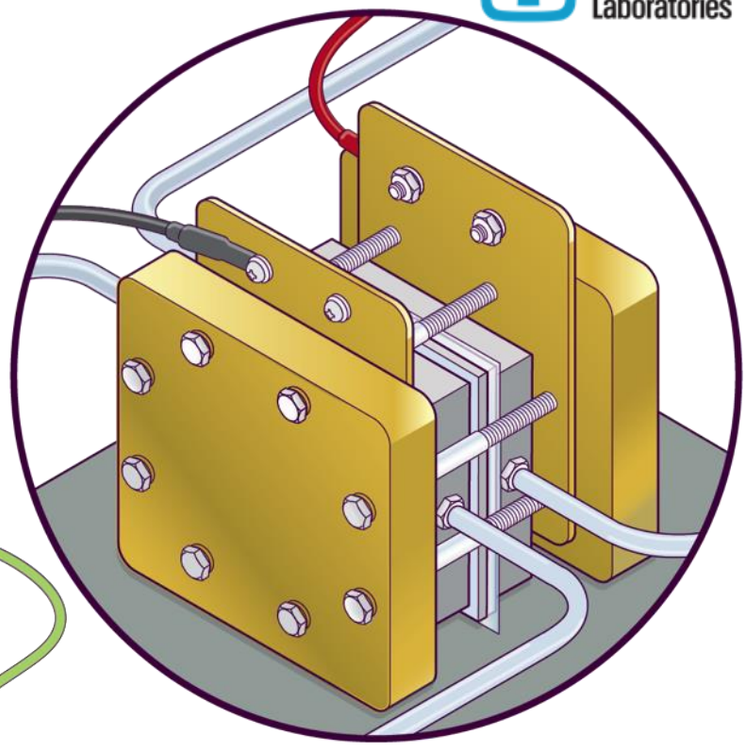
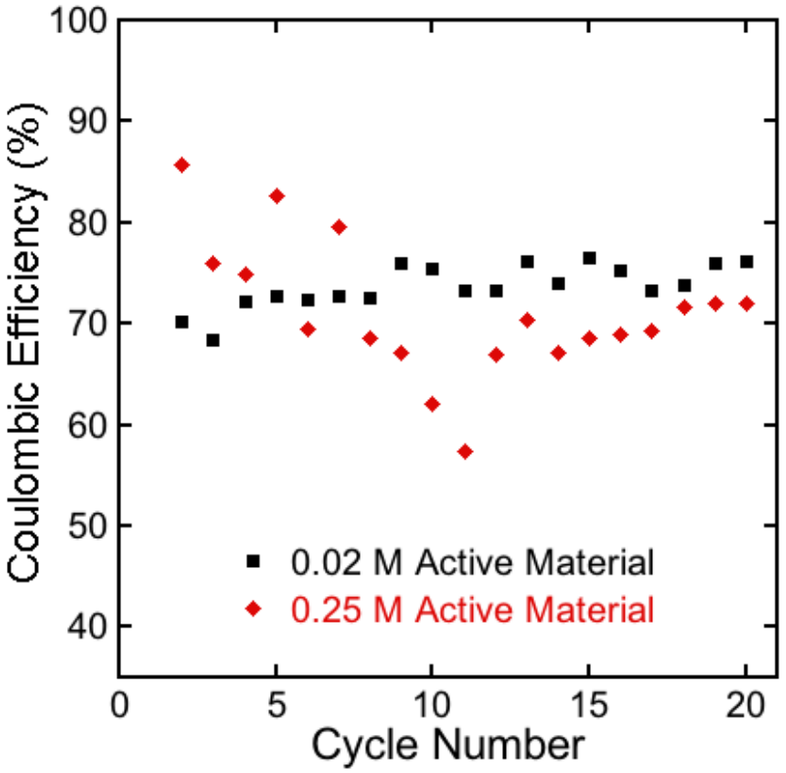


Lab Scale Prototype

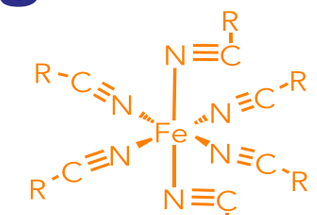


FY14 Focus: Non-aqueous electrolyte/membrane compatibility

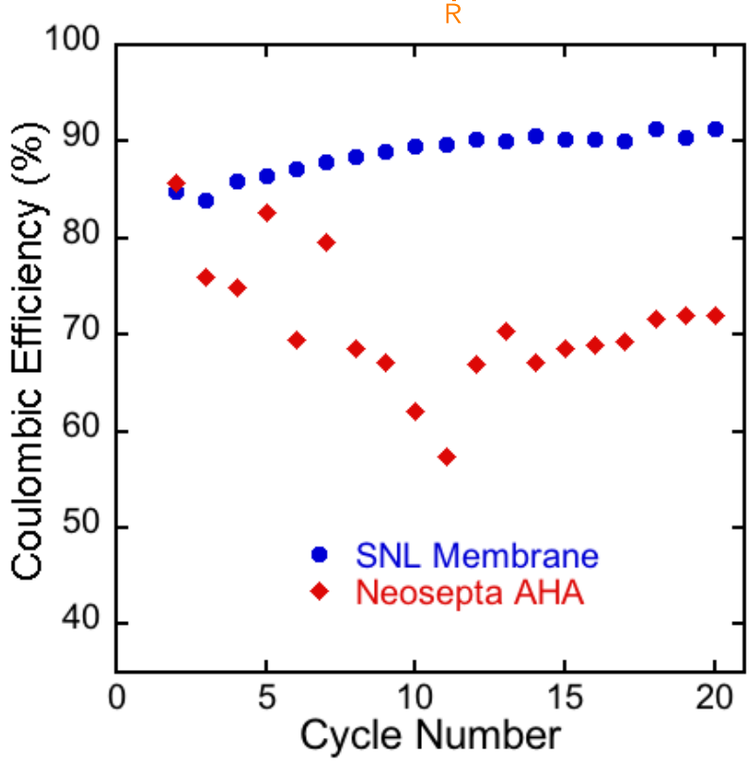
Flow Cell Testing



- **Initial tests on Cu-MetIL/Fe-MetIL (1.5 V) system used commercial membranes.**
- **Neosepta AHA gave the best results.**
- **Batteries were run at 25 °C and 50 °C**
- **Increased concentration gave more scatter in the data but higher energy density.**

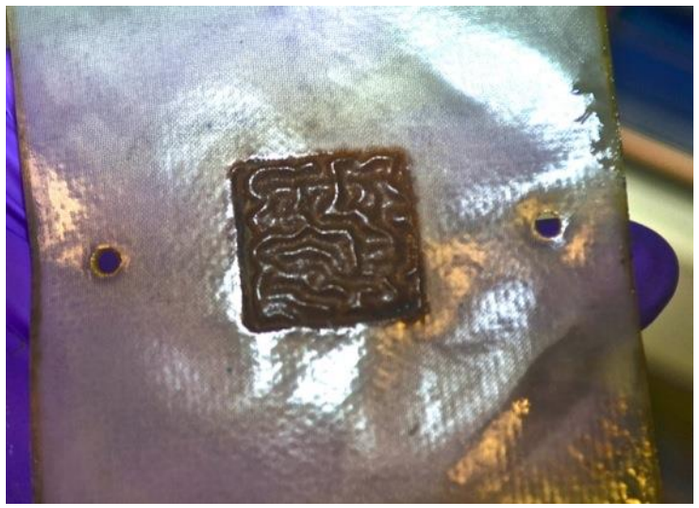


- **Tunable membranes were investigated to improve battery performance.**
- **Coulombic efficiency increased from 70% to 90%.**
- **Current density was increased from 0.5 mA/cm² to 10 mA/cm².**



Membranes

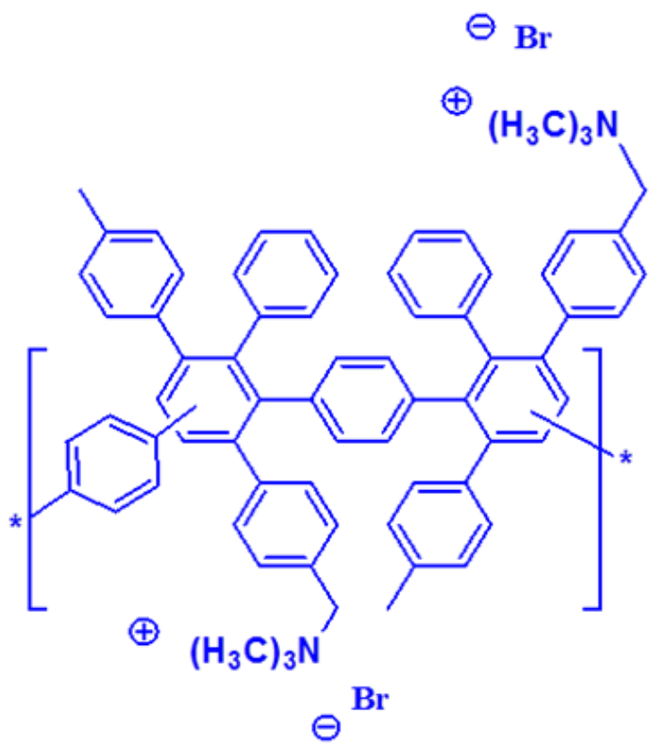
Commercially available, ion selective membranes are not designed for non-aqueous use.



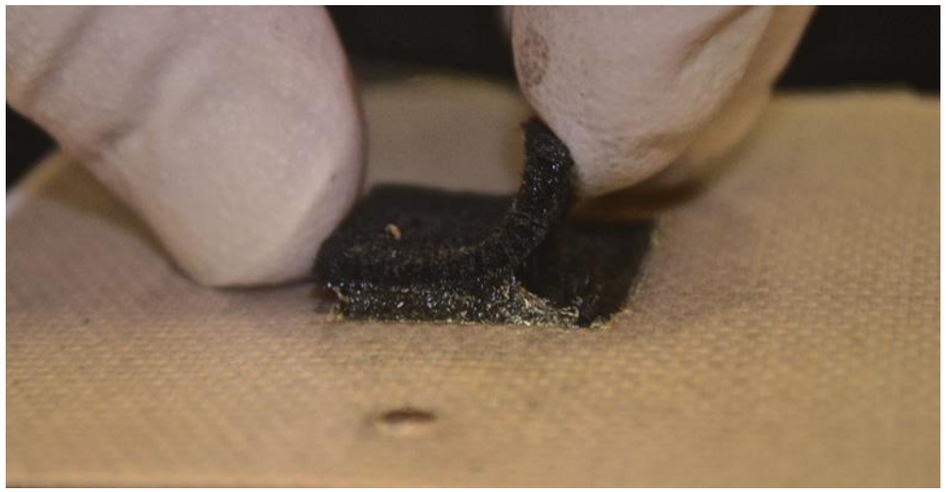
Ionic Liquid

Ionic Liquid/Acetonitrile

Neosepta® AHA

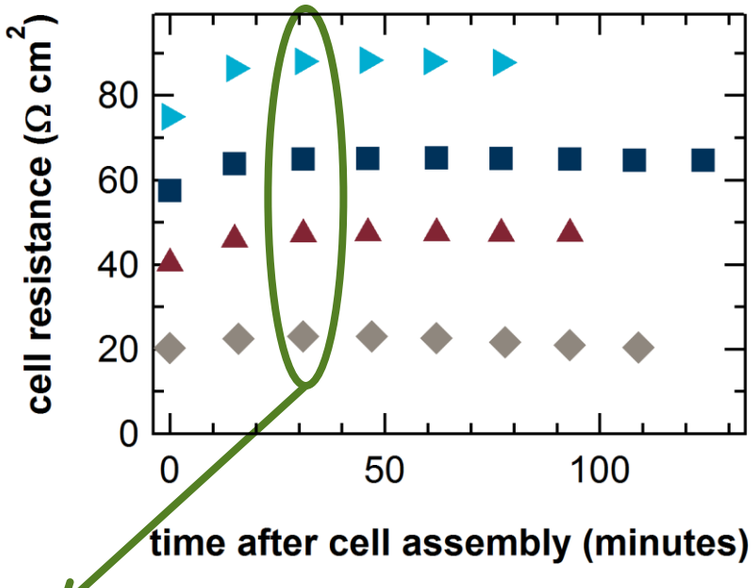


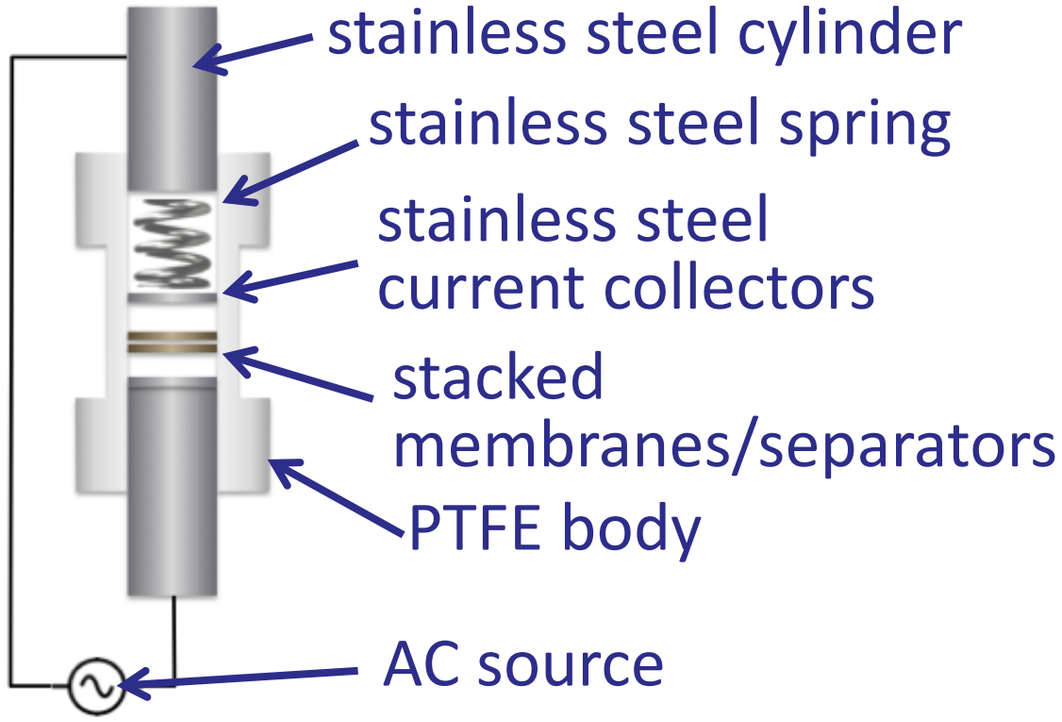
Sandia technology membranes are now being tested because their detailed chemical structures are known.

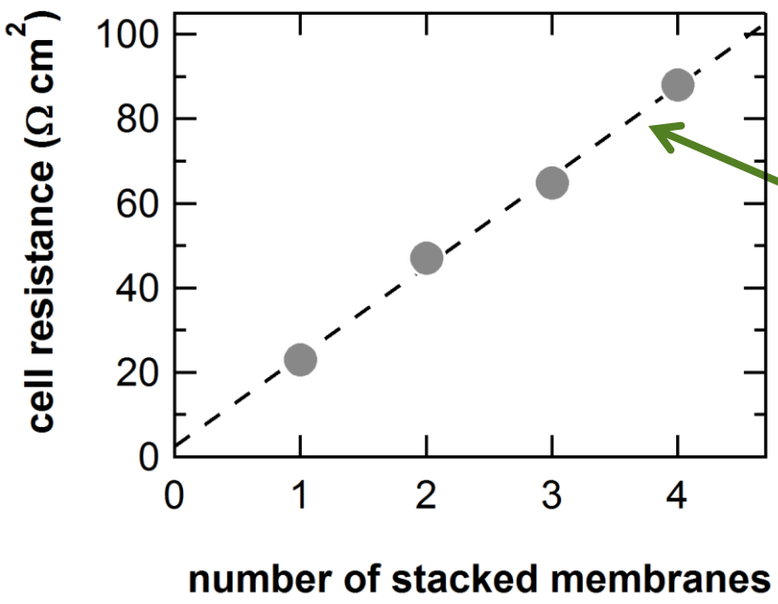


Membrane Characterization

Electrochemical impedance spectroscopy (EIS) was used to measure the through-plane resistance of various membranes/separators.







slope of fitted line = 21.3 Ω cm²
≡ area-specific resistance of membrane without contact resistance

Through-Plane Resistance (EIS)

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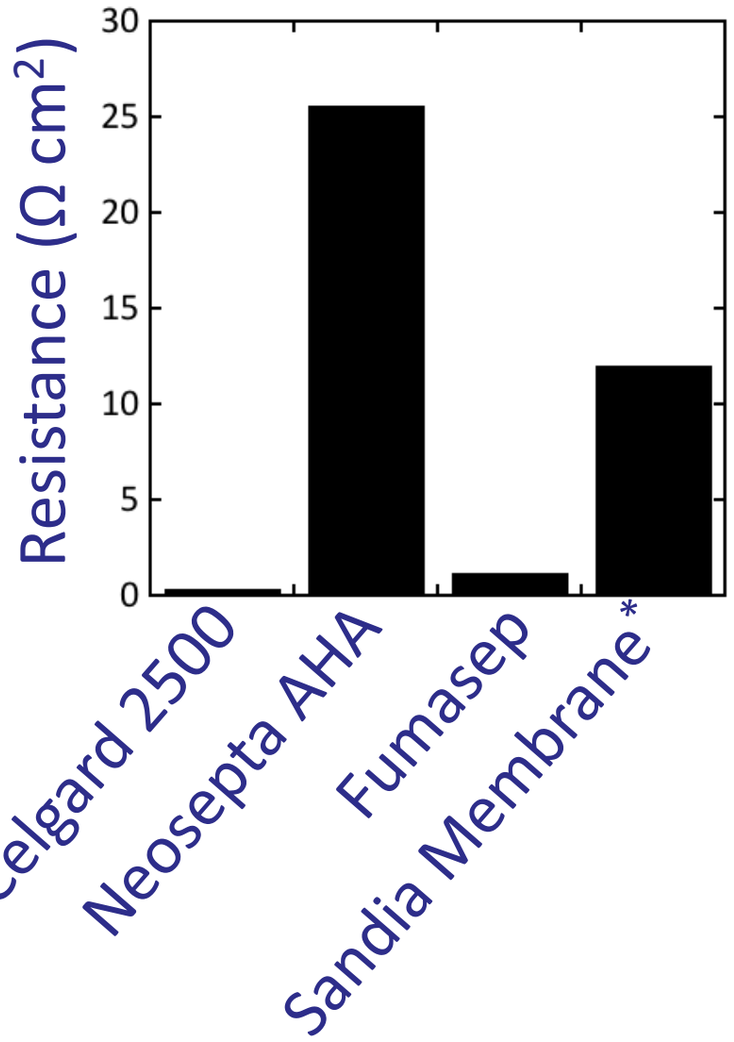
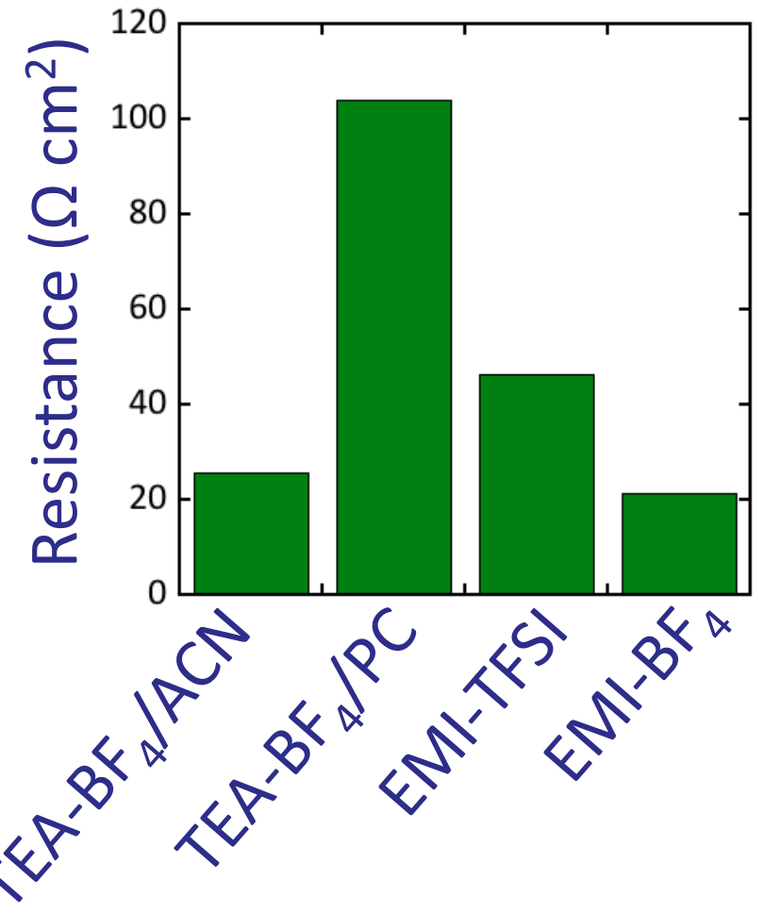
Membranes in 0.5 M TEA-BF_4/ACN



The goal is to obtain the **low ionic resistance** of Celgard with higher selectivity.

Neosepta AFX in Different Solvents



Different membranes in TEA-BF_4 illustrate a wide variability in resistances that in turn are solvent dependent. Ion selectivity is also crucial, and these evaluations are currently underway.

*Cy Fujimoto

Summary/Conclusions

Project Summary/Goal

Metallic ionic liquid flow batteries offer the potential of high energy densities compared to aqueous flow batteries due to larger voltage windows, but are limited by their high viscosity. This project is revolutionizing flow batteries through new multivalent solutions, non-aqueous membranes, and cell designs.

FY14 Accomplishments

- Developed new iron-based ligands resulting in a 40% increase in voltage window-smaller footprint; energy security
- As of FY14, published 8 articles, 13 conference papers, two journal covers, and submitted 4 patents-leading edge R&D

FY15-16 Plans

- Move toward a more viable system through–
  - Robust membranes for higher cycle life-materials compatibility
  - Increasing charge/discharge rates through higher surface area cells-lower R&D cost
  - Reducing over-voltages through interdigitated cell design-reduced cell wear

Thank you to the DOE OE and especially Dr. Imre Gyuk for his dedication and support to the ES industry and Sandia's ES Program.

Questions?

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